



US009003177B2

(12) **United States Patent**
Rollins

(10) **Patent No.:** **US 9,003,177 B2**
(45) **Date of Patent:** ***Apr. 7, 2015**

(54) **DATA SECURITY FOR DIGITAL DATA STORAGE**

USPC 713/150
See application file for complete search history.

(75) Inventor: **Doug L. Rollins**, Nampa, ID (US)

(56) **References Cited**

(73) Assignee: **Micron Technology, Inc.**, Boise, ID (US)

U.S. PATENT DOCUMENTS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

4,150,404 A	4/1979	Tercic et al.	
4,262,329 A	4/1981	Bright et al.	
4,493,028 A	1/1985	Heath	
4,588,991 A	5/1986	Atalla	
4,799,258 A	1/1989	Davies	
4,864,616 A *	9/1989	Pond et al.	713/165
4,873,645 A	10/1989	Hunter et al.	
4,903,296 A	2/1990	Chandra et al.	
5,007,082 A	4/1991	Cummins	
5,052,040 A	9/1991	Preston et al.	

(21) Appl. No.: **13/481,623**

(Continued)

(22) Filed: **May 25, 2012**

OTHER PUBLICATIONS

(65) **Prior Publication Data**

US 2012/0233454 A1 Sep. 13, 2012

Doyle, Ed., "The Comprehensive Standard for Business, School, Library, and Home," Microsoft Press, 2nd Ed., (1994) pp. 249, 271,342, 355.

Related U.S. Application Data

(Continued)

(60) Continuation of application No. 12/557,334, filed on Sep. 10, 2009, now Pat. No. 8,191,159, which is a continuation of application No. 11/521,163, filed on Sep. 14, 2006, now Pat. No. 7,594,257, which is a division of application No. 09/818,699, filed on Mar. 27, 2001, now Pat. No. 7,526,795.

Primary Examiner — David Garcia Cervetti

(74) *Attorney, Agent, or Firm* — Gazdzinski & Associates, PC

(51) **Int. Cl.**

H04L 29/06 (2006.01)

G06F 21/60 (2013.01)

H04L 29/08 (2006.01)

(57) **ABSTRACT**

A computing system includes data encryption in the data path between a data source and data storage devices. The data storage devices may be local or they may be network resident. The data encryption may utilize a key which is derived at least in part from an identification code stored in a non-volatile memory. The key may also be derived at least in part from user input to the computer. In a LAN embodiment, public encryption keys may be automatically transferred to a network server for file encryption prior to file transfer to a client system.

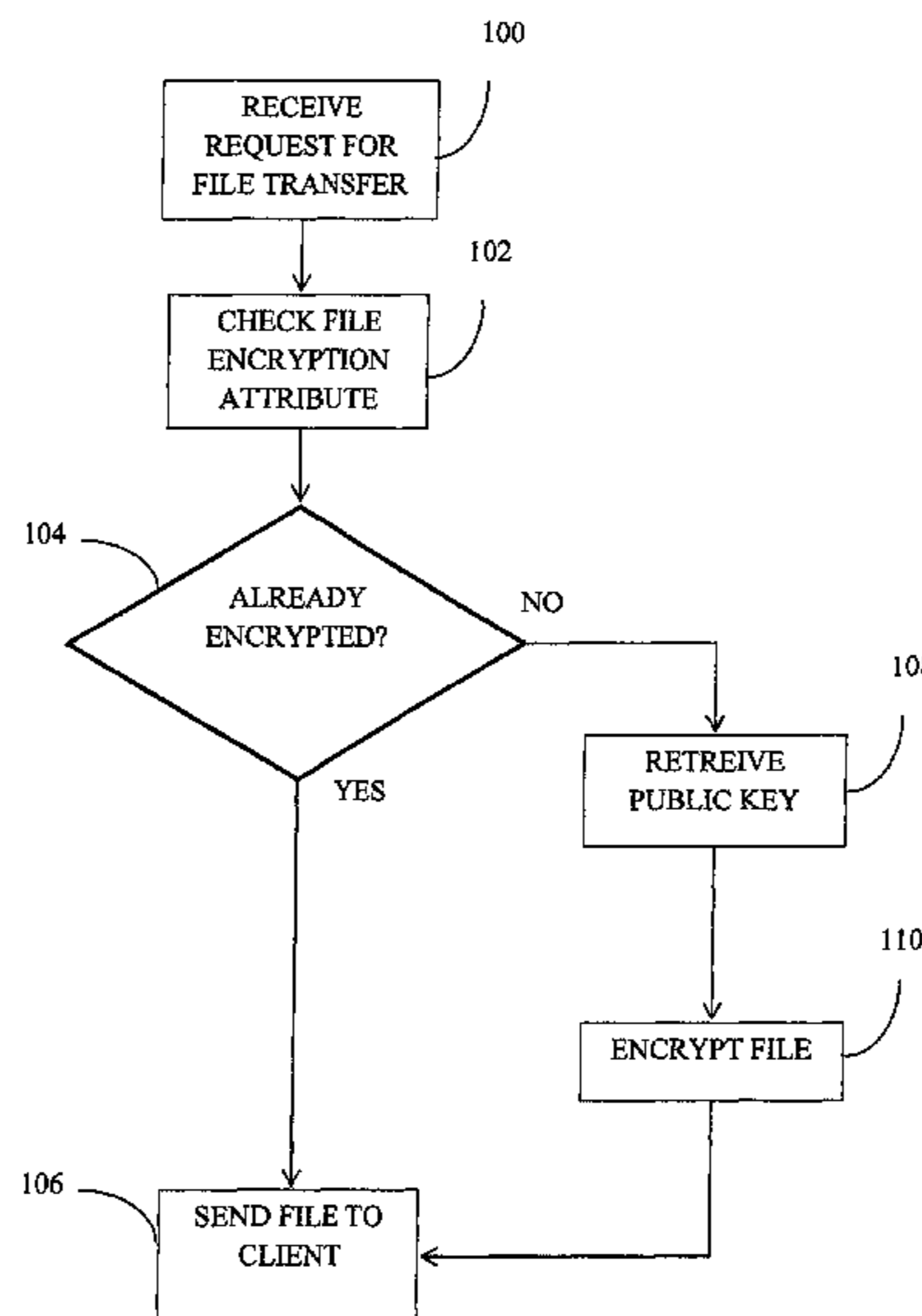
(52) **U.S. Cl.**

CPC **H04L 63/0442** (2013.01); **G06F 21/602** (2013.01); **G06F 21/606** (2013.01); **H04L 63/062** (2013.01); **H04L 63/104** (2013.01); **H04L 67/06** (2013.01)

(58) **Field of Classification Search**

CPC .. G06F 21/6218; G06F 21/602; G06F 21/606

18 Claims, 5 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

5,068,894 A 11/1991 Hoppe
 5,142,578 A 8/1992 Matyas et al.
 5,212,729 A 5/1993 Schafer
 5,231,662 A 7/1993 Van Rumpt et al.
 5,235,641 A 8/1993 Nozawa et al.
 5,265,159 A 11/1993 Kung
 5,317,638 A 5/1994 Kao et al.
 5,325,430 A 6/1994 Smyth et al.
 5,343,525 A 8/1994 Hung et al.
 5,375,243 A 12/1994 Parzych et al.
 5,379,344 A 1/1995 Larsson et al.
 5,394,469 A 2/1995 Nagel et al.
 5,402,492 A 3/1995 Goodman et al.
 5,442,706 A 8/1995 Kung
 5,513,262 A * 4/1996 van Rumpt et al. 380/29
 5,563,950 A 10/1996 Easter et al.
 5,584,023 A * 12/1996 Hsu 1/1
 5,592,549 A 1/1997 Nagel et al.
 5,606,610 A 2/1997 Johansson
 5,615,262 A 3/1997 Guy et al.
 5,623,546 A 4/1997 Hardy et al.
 5,631,960 A 5/1997 Likens et al.
 5,646,993 A 7/1997 Aizawa
 5,680,453 A 10/1997 Akiyama et al.
 5,682,549 A 10/1997 Tanaka et al.
 5,734,819 A 3/1998 Lewis
 5,745,568 A 4/1998 O'Connor et al.
 5,796,828 A 8/1998 Tsukamoto et al.
 5,796,840 A 8/1998 Davis
 5,818,939 A 10/1998 Davis
 5,857,021 A * 1/1999 Kataoka et al. 705/54
 5,857,024 A * 1/1999 Nishino et al. 713/172
 5,892,826 A 4/1999 Brown et al.
 5,978,815 A * 11/1999 Cabrera et al. 1/1
 6,032,257 A 2/2000 Olarig et al.
 6,044,155 A * 3/2000 Thomlinson et al. 713/155
 6,081,835 A 6/2000 Antcliff et al.
 6,085,238 A 7/2000 Yuasa et al.
 6,094,721 A 7/2000 Eldridge et al.
 6,185,546 B1 2/2001 Davis
 6,185,681 B1 * 2/2001 Zizzi 713/165
 6,199,163 B1 * 3/2001 Dumas et al. 713/183
 6,216,230 B1 4/2001 Rallis et al.
 6,249,866 B1 * 6/2001 Brundrett et al. 713/165
 6,286,008 B1 9/2001 Matsumoto et al.
 6,310,692 B1 10/2001 Fan et al.
 6,327,608 B1 12/2001 Dillingham
 6,343,282 B1 1/2002 Oshima
 6,490,680 B1 * 12/2002 Scheidt et al. 713/166
 6,606,690 B2 8/2003 Padovano
 6,615,349 B1 * 9/2003 Hair 713/165
 6,668,323 B1 12/2003 Challener et al.
 6,678,821 B1 * 1/2004 Waugh et al. 713/168
 6,701,324 B1 3/2004 Nair et al.
 6,721,424 B1 * 4/2004 Radatti 380/286
 6,725,370 B1 * 4/2004 Sakakura 713/155
 6,785,812 B1 8/2004 Botham et al.
 6,789,195 B1 9/2004 Prihoda et al.
 6,857,076 B1 * 2/2005 Klein 713/189
 6,862,103 B1 3/2005 Miura et al.
 6,876,835 B1 4/2005 Marko et al.
 6,941,454 B1 * 9/2005 Spraggs 713/150
 6,947,556 B1 * 9/2005 Matyas et al. 380/29
 6,976,165 B1 * 12/2005 Carpentier et al. 713/165
 6,985,719 B2 * 1/2006 Leppinen et al. 455/412.1

6,986,043 B2 * 1/2006 Andrew et al. 713/166
 7,010,689 B1 3/2006 Matyas et al.
 7,024,474 B2 4/2006 Clubb et al.
 7,036,149 B2 * 4/2006 Sonoda et al. 726/27
 7,089,271 B1 * 8/2006 Kihara et al. 1/1
 7,093,137 B1 * 8/2006 Sato et al. 713/193
 7,096,370 B1 8/2006 Klein
 7,100,007 B2 * 8/2006 Saika 711/162
 7,124,190 B1 10/2006 Moore
 7,130,426 B1 * 10/2006 Cha et al. 380/201
 7,178,021 B1 2/2007 Hanna et al.
 7,203,314 B1 * 4/2007 Kahn et al. 380/239
 7,277,548 B2 * 10/2007 Park et al. 380/270
 7,284,131 B2 * 10/2007 Chu 713/182
 7,290,279 B2 * 10/2007 Eun et al. 726/9
 7,350,084 B2 * 3/2008 Abiko et al. 713/193
 7,362,868 B2 * 4/2008 Madoukh et al. 380/277
 7,373,517 B1 * 5/2008 Riggins 713/184
 7,428,306 B2 * 9/2008 Celikkan et al. 380/28
 7,437,429 B2 * 10/2008 Pardikar et al. 709/219
 7,457,414 B1 * 11/2008 Kahn et al. 380/201
 7,463,738 B2 * 12/2008 Nii 380/232
 7,496,767 B2 * 2/2009 Evans 713/193
 7,506,367 B1 * 3/2009 Ishibashi 726/10
 7,565,532 B2 * 7/2009 Pham et al. 713/165
 7,650,643 B2 * 1/2010 Ishikawa et al. 726/26
 7,698,565 B1 * 4/2010 Bjorn et al. 713/186
 7,827,613 B2 * 11/2010 Koved et al. 726/26
 8,352,679 B2 * 1/2013 Wolfe et al. 711/118
 8,565,436 B2 * 10/2013 Mansour et al. 380/281
 8,726,043 B2 * 5/2014 Wolfe et al. 713/193
 2001/0001876 A1 * 5/2001 Morgan et al. 713/171
 2001/0039659 A1 11/2001 Simmons et al.
 2001/0054099 A1 12/2001 Campbell et al.
 2002/0010860 A1 * 1/2002 Chu 713/182
 2002/0019935 A1 * 2/2002 Andrew et al. 713/165
 2002/0114453 A1 * 8/2002 Bartholet et al. 380/44
 2002/0141588 A1 * 10/2002 Rollins 380/277
 2002/0169971 A1 * 11/2002 Asano et al. 713/193
 2002/0184494 A1 * 12/2002 Awadalla 713/160
 2002/0184508 A1 * 12/2002 Bialick et al. 713/182
 2003/0023847 A1 * 1/2003 Ishibashi et al. 713/169
 2003/0037261 A1 * 2/2003 Meffert et al. 713/201
 2003/0046366 A1 * 3/2003 Pardikar et al. 709/219
 2003/0172280 A1 * 9/2003 Scheidt et al. 713/182
 2004/0044696 A1 3/2004 Frost
 2004/0091114 A1 * 5/2004 Carter et al. 380/259
 2007/0294544 A1 * 12/2007 Ishikawa et al. 713/193
 2009/0307504 A1 * 12/2009 Ishikawa et al. 713/193
 2010/0150352 A1 * 6/2010 Mansour et al. 380/281
 2010/0281223 A1 * 11/2010 Wolfe et al. 711/133
 2010/0281247 A1 * 11/2010 Wolfe et al. 713/150
 2010/0287385 A1 * 11/2010 Conte et al. 713/193
 2013/0283060 A1 * 10/2013 Kulkarni et al. 713/189

OTHER PUBLICATIONS

Konheim, Allen G., "Cryptography, A Primer", 1981, John Wiley and Sons, New York, pp. 348-363.
 Microsoft Computer Dictionary, Third edition, 1997, Microsoft Press, pp. 332, 413.
 Microsoft Press—Computer Dictionary Second Edition, 1994, pp. 249, 271, 355.
 Microsoft Press—Computer Dictionary Second Edition, 1994, pp. 271, 342.
 Schneier, Applied Cryptography, 1996. John Wiley and Sons, Inc., Second edition, pp. 4-5.

* cited by examiner

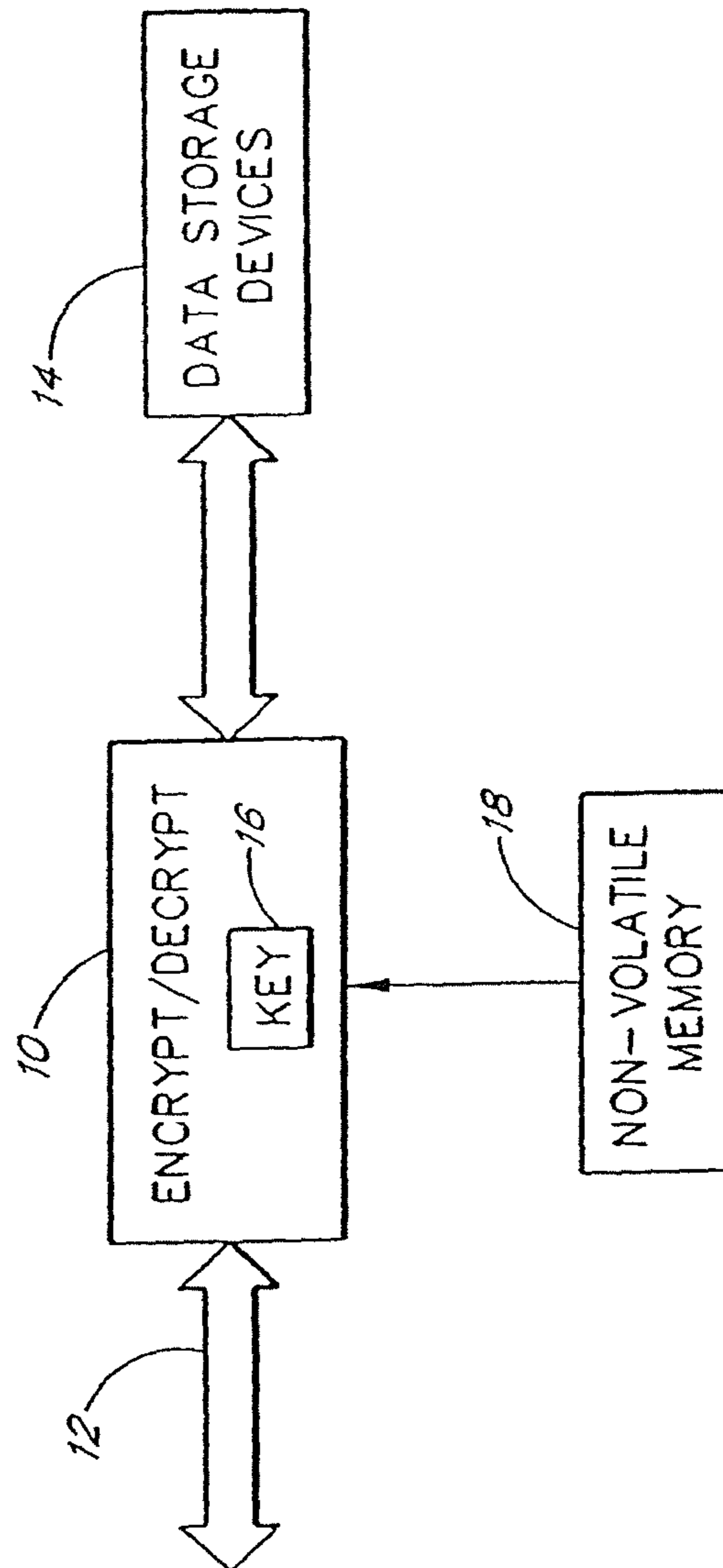


FIG. 1

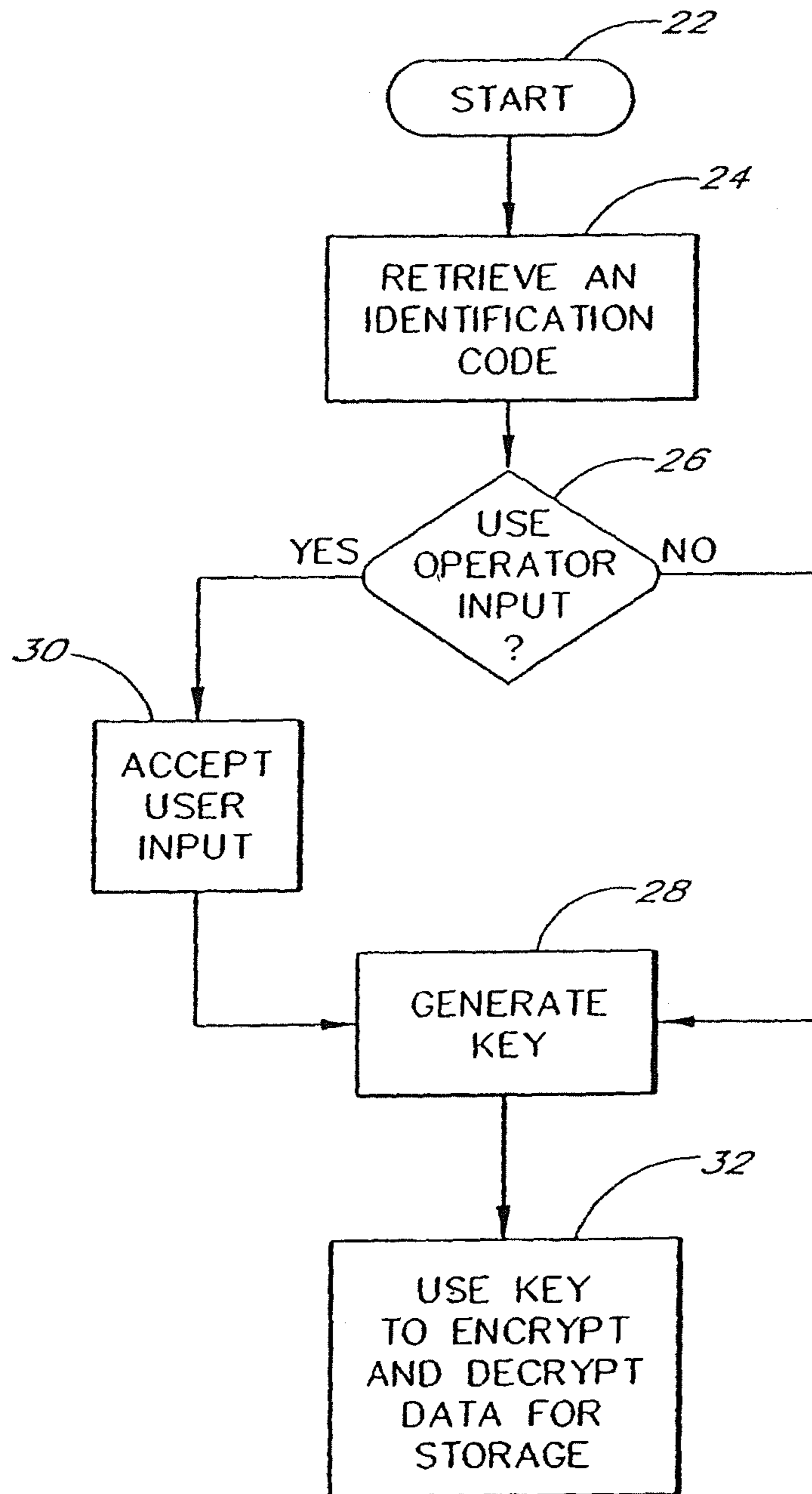


FIG. 2

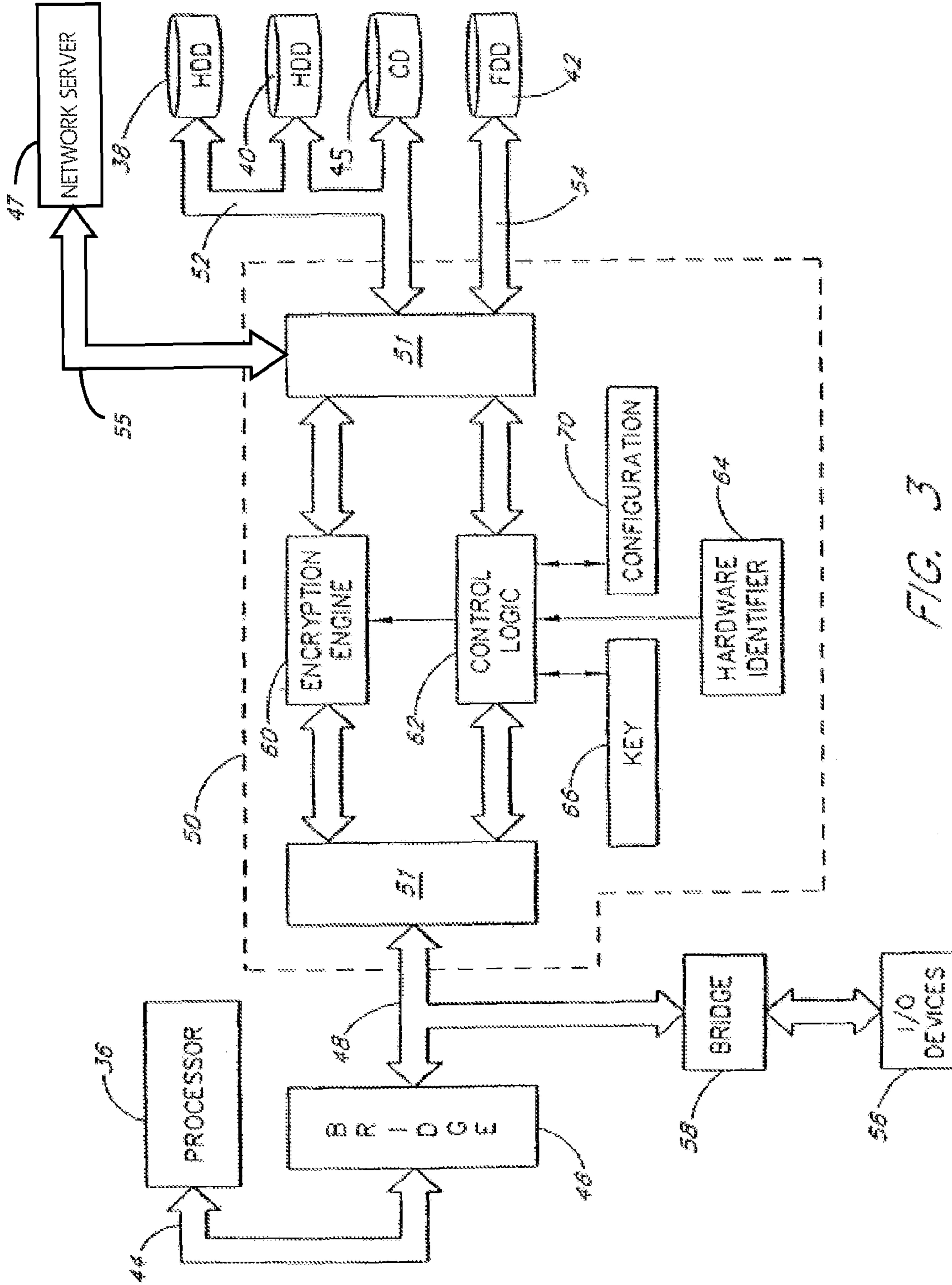


FIG. 3

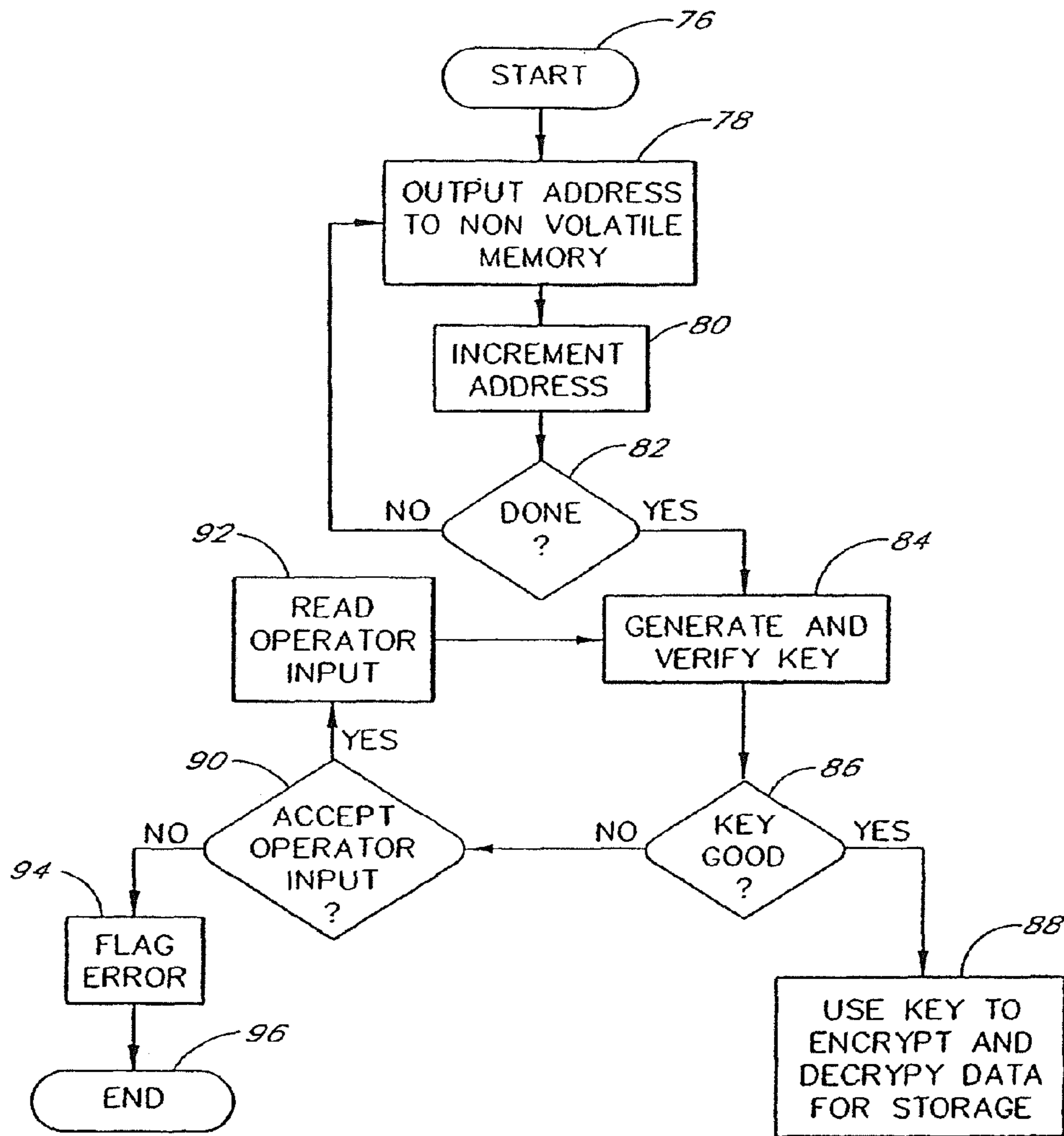


FIG. 4

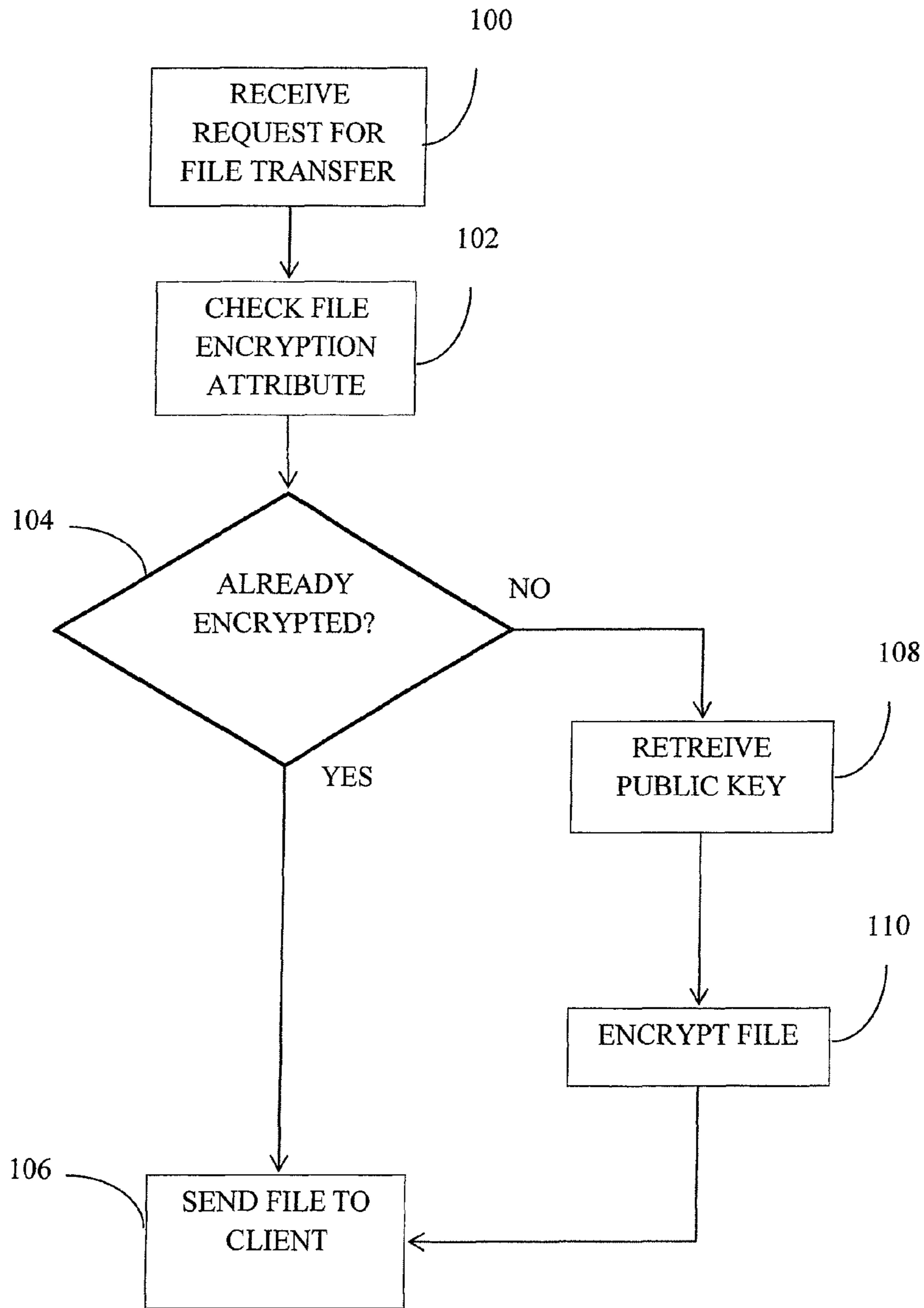


FIG. 5

DATA SECURITY FOR DIGITAL DATA STORAGE

This application is a continuation of and claims priority to U.S. patent application Ser. No. 12/557,334 of the same title filed Sep. 10, 2009, now U.S. Pat. No. 8,191,159, which is a continuation of U.S. patent application Ser. No. 11/521,163 filed Sep. 14, 2006, now U.S. Pat. No. 7,594,257, which is a divisional of U.S. patent application Ser. No. 09/818,699, filed Mar. 27, 2001, now U.S. Pat. No. 7,526,795, each of the foregoing incorporated herein by reference in its entirety.

BACKGROUND

1. Field

The invention relates to methods and apparatus for providing security for digital data stored on personal computers and network servers on data storage media such as magnetic and optical disks and tapes.

2. Description of the Related Art

Over the past several years, personal computing systems have become more powerful, smaller, and less expensive. As this has occurred, more and more computing applications are performed on personal computer platforms. Local and wide area networks of personal computers are now often used in corporate and business applications instead of the large mainframes used for the same applications in the past. A further result of the increases in performance and decreases in price of personal computers is a dramatic increase in personal computer use for household financial and other sensitive and preferably confidential information.

The use of personal computers in these applications raises data security and privacy issues, which have thus far been insufficiently resolved. Laptop and other personal computers, as well as the removable data storage media used in them are transported, mislaid, lost, and sometimes stolen. Consequently, security and privacy issues which were not present when computers and their data storage media were generally fixed have now become prominent. Administrators of computer resources in the business environment must remain aware of the location of portable computing devices as well as the nature of the programs and data stored on them. For home users, concerns arise if credit card, social security, or bank account numbers are present on fixed or removable media which may be lost or stolen. In the network environment, sensitive or confidential data may be stored on resources available to several users.

To resolve a few of these concerns, some programs allow the user to password protect documents or files, thereby preventing access to the data in the file unless the password is known. This provides limited security, however, since these schemes are easy to defeat with widely available password extraction programs. Furthermore, although the act of opening the file may be restricted in the relevant application program, the data itself resides on the media in raw form, and may still be extracted by a trained computer user.

Systems have also been proposed which perform encryption on data and application programs stored on tape and disk. These systems provide improved security over the password protection described above. As one example, a system disclosed in U.S. Pat. No. 5,325,430 to Smyth et al. (incorporated herein by reference in its entirety) includes a security module attached to a personal computer which performs data and application program encryption. The security module communicates with a removable smart card assigned to a given user which contains encryption keys used by the security module. Although the security provided by this system is

adequate for many applications, the circuitry used to implement the system is complex, and administration of the system for producing and assigning keys and smart cards is time consuming and expensive.

Another system for encrypting files is disclosed in U.S. Pat. No. 5,235,641 to Nozawa et al., the disclosure of which is also incorporated herein by reference in its entirety. In this system, data stored to a magnetic tape is encrypted by a cryptographic adapter which is located in the data path between a host processor and a tape drive. In this system, the host processor generates cryptographic keys which are stored on the tape itself. This requires additional logic to encrypt the keys as well as the data, and consequently, this system requires relatively complex circuitry, and leaves the key potentially recoverable from the tape itself if the key encryption scheme is broken.

Thus, existing encryption systems for personal and portable computers have serious drawbacks, and have not been widely implemented. In particular, a system which is useful for both an individual personal computer user and users connected through a computer network has not been heretofore provided. Such a system should provide data security with flexibility and without expensive administration or implementation.

SUMMARY

In a first aspect, an apparatus configured to store data is disclosed. In one embodiment, the apparatus includes a first apparatus configured to receive an encryption key generated by a first computer, the encryption key uniquely associated at least in part with a user of the first computer, a second apparatus configured to obtain encrypted data via the first computer, the encrypted data having been generated using the encryption key, a third apparatus configured to receive a file attribute to be stored, the file attribute in association with the encrypted data denoting the data as encrypted, and further indicating a source of the encryption key, a fourth apparatus configured to cause an indication of a source of the encrypted data to be stored, and logic configured to cause the apparatus to when a request is received from a requestor for the encrypted data, and the requestor is the source of the encrypted data, forward the encrypted data to the requestor and when the request is received from the requestor for non-encrypted data, encrypt the non-encrypted data with the encryption key associated with the requestor and forward the encrypted data to the requestor.

In a second aspect, a computerized storage system is disclosed. In one embodiment, the storage system includes a storage device and a processor in data communication with the storage device. The processor is configured to execute at least one computer program including a plurality of instructions configured to, when executed by the processor: receive a user-specific encryption key, receive user-specific information enabling an authorized entity to access first data based at least in part on an association of the user-specific information and the first data, encrypt the first data upon a determination that the first data has not been previously encrypted as a first encrypted data, using at least the user-specific encryption key so as to produce the first encrypted data, store the first encrypted data and the user-specific information on the storage device, receive a request for access to the first encrypted data, determine, based at least in part on the stored user-specific information, whether the request is received from the authorized entity, and when it is determined that the request is received from the authorized entity, provide the requested first encrypted data thereto.

In a third aspect, a method of storing data in a computerized storage system is disclosed. In one embodiment, the method includes generating an encryption key using a first computer, the encryption key being uniquely associated at least in part with a user, encrypting data using the encryption key and a first computer to generate first encrypted data, causing the first encrypted data to be stored on a computerized storage device, the computerized storage device connected via a network to the first computer, and providing an attribute to be stored on the computerized storage device, the attribute in association with the first encrypted data (i) designating the first encrypted data as encrypted, and (ii) indicating an association between the user and the encryption key, wherein the attribute is configured to cause requested data that has not been previously encrypted to be encrypted using the encryption key to generate second encrypted data, the second encrypted data to be provided to a source of a request for the requested data.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a data storage system incorporating an embodiment of the invention.

FIG. 2 is a flow chart illustrating acts performed during key generation in an embodiment of the invention.

FIG. 3 is a block diagram illustrating an encrypting data path passing from a host processor to data storage devices, in accordance with one embodiment of the invention.

FIG. 4 is a flow chart illustrating acts performed during key generation in another embodiment of the invention.

FIG. 5 is a flow chart of a process of encrypted file transfer in a network environment in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the invention will now be described with reference to the accompanying Figures, wherein like numerals refer to like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any limited or restrictive manner, simply because it is being utilized in conjunction with a detailed description of certain specific embodiments of the invention. Furthermore, embodiments of the invention may include several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the invention herein described.

Referring now to FIG. 1, a data storage system is illustrated which incorporates aspects of the invention. The system includes encryption/decryption logic 10 that is connected to receive digital data from a data bus 12. The encryption/decryption logic 10 is configured to forward data received from the data bus 12 to data storage devices 14 in an encrypted form. The data or information transferred between the data bus 12 and the data storage devices may comprise application programs themselves, data used by application programs, or any other information that the host computing system stores to the data storage devices 14 of the system. As will be further explained below with reference to FIGS. 2 and 3, the encryption/decryption logic may in some embodiments be configurable to perform the encryption and decryption on a selectable subset of the data storage devices if desired by a user of the system.

The algorithm used to perform the encryption may comprise any known encryption algorithm, and many different alternatives will be well known to those of skill in the art. In many applications, the encryption and decryption process

will be defined in part by a key 16 which is utilized by the encryption/decryption logic 10 to perform the data manipulation which results in data encryption and decryption. In some systems, the same key is used for both the encryption and decryption processes, but in others, the key 16 may comprise a pair of keys, wherein one is used for encryption, and the other for decryption. Public key cryptographic systems, where an encryption key is publicly available and a decryption key is maintained secret by a user, is one example of such a system. Given the variety of encryption and decryption schemes which have been and are currently being developed, the use of the word "key" is intended to encompass any piece of information, data, parameter, definition, configuration of logic circuitry, or other entity or circuit arrangement which serves at least in part to configure the encryption/decryption logic, or to otherwise in any way partly or wholly define the data encryption process which is performed by the encryption/decryption logic 10.

Also provided in the system of FIG. 1 is a non-volatile memory location 18. As is well known in the art, a non-volatile memory has the property that the data or information stored in it remains when the host system is powered down. Non-volatile memory may comprise battery backed up RAM, EPROM, EEPROM, or ROM memory circuitry, for example. In the application of FIG. 1, this memory location 18 may advantageously store an identification code. The stored identification code may be used to derive, at least in part, the key 16 which is used in the encryption process. This derivation may involve simply making the key the identification code itself, or may alternatively involve a logical or mathematical manipulation or transformation of the identification code to produce the key. In some embodiments, as will be further explained below, the key 16 may be derived in part from the identification code stored in the non-volatile memory and in part from a password or other piece of information entered by a user of the computing system.

The system of FIG. 1 includes many advantages over prior art data encryption schemes and is especially applicable to individual personal computer and laptop computer users. In some embodiments, the circuitry of FIG. 1 may be incorporated into, for example, a laptop computer which is sold to an individual for household and/or business use. In most of these situations, the purchased computer will not be a member of a group of computers which is controlled or overseen by a system administrator that will create and assign encryption keys, smart cards, etc. Rather, the laptop will be simply used as is, for both personal and business use by a user who is generally unfamiliar with data security techniques or procedures.

In these embodiments, the identification code may comprise a multi-bit data word which is associated with the individual laptop being used. When stored in a non-erasable memory element such as ROM or EPROM, the identification code may be substantially permanently associated with the individual laptop being used. It will be appreciated that data security in these environments is enhanced if different laptops do not typically share a common identification code. When this is true, the key 16 derived from the identification code will be different in different laptops produced by the laptop manufacturer. It will therefore also be appreciated that the data stored on the data storage devices 14 will be encrypted differently by different laptops. Thus, a removable media such as a floppy disk, tape, or writeable CD will not be useable on any computer except the one that originally stored the data. Thus, a level of security is provided for removable media which may be lost, mislaid, or stolen.

5

It will also be appreciated that this level of security is provided without any intervention by the user or a system administrator. Key generation and data encryption is automatic and transparent. In addition, this data security scheme is easily implemented in the large scale production of laptops and other personal computers. Machine specific data encryption may be provided with the simple provision of non-volatile storage of information which defines the data encryption process performed. This information may advantageously be substantially uniquely associated with the host computing logic or host computer. This may be ensured by using some form of sequential numbering scheme for the identification code, or alternatively a random or pseudo-random numbering scheme with a low probability of producing two identical identification codes for different laptops. However, it may be noted that it is not necessary to absolutely guarantee that each laptop have a uniquely defined encryption process. The desirable feature is that there be a relatively low probability that lost or stolen media will be readable in some other laptop or personal computer available to someone who has found or has stolen the media elements. Therefore, duplicate identification codes and keys defining identical encryption processes may be provided within a given set of computers while still maintaining a useful level of security. Thus, the association between identification codes and their respective host computers need only be substantially unique such that a reasonable level of security is created.

FIG. 2 illustrates a method of key generation and data encryption according to one embodiment of the invention. It will be appreciated that the method shown in FIG. 2 may, in one embodiment, be implemented on hardware illustrated in FIG. 1.

The method begins at a start state 22, and moves from there to step 24, where an identification code is retrieved. The identification code may be stored in a non-volatile memory, and may in addition be substantially uniquely associated with specific host computer hardware.

The system then moves to decision state 26, where it is decided whether or not some user input should be utilized in the process of encryption key generation. If not, the method moves directly to step 28, where an encryption key is generated using the identification code retrieved at step 24. If user input is to be used in key generation, the method moves from step 26 to step 30, where the user input is accepted by the system. The user input may, for example, comprise an alphanumeric code which is typed into the computer keyboard by the user in response to a system prompt. Following this, the method moves to step 28, where the key is generated using both the identification code and the user input. The user input from step 30 may be an alphanumeric sequence which is converted to a multi-bit word (for example, to ASCII code). This word may be combined with the identification code in many ways, including concatenation as one simple example, or other more complicated logical or mathematical manipulations may be used.

Following key generation at step 28, the key is used to encrypt and decrypt data that is stored to and retrieved from a data storage device at step 32. In the personal computer or laptop computer context, the series of steps leading to and including key generation may be performed during the boot operation prior to any accesses to encrypted data storage devices. In these embodiments, all data, programs, etc. stored on the data storage devices are encrypted with the same key, a key which may require some user input to generate as described above. The computer may be either factory configured or user configured to require or not require user input for key generation.

6

The addition of user input to key generation provides an enhancement to data security beyond that provided when only the identification code is used to derive an encryption key. This is because if the entire computer is lost or stolen, when the computer is turned on only the computer owner will know what code or password to input in order to generate the proper key at step 28 of FIG. 2. Thus, access to encrypted programs and data is effectively prevented even with the original computer the hands of an unauthorized user.

An embodiment of the invention is also illustrated in FIG. 3 which may be used to implement the process described above with reference to FIG. 2. In this Figure, a computer system is shown having a host processor 36, which may, for example, comprise a member of the Pentium family of processors such as the Pentium, Pentium Pro, or Pentium II. Although industry standard PC architecture is used as an illustrative example in this Figure, it will be appreciated that many computer designs may be implemented using the principles illustrated herein. Also provided as part of the computer system of FIG. 3 are a plurality of data storage devices, including hard disk drives 38, 40, a floppy disk drive 42 and a CD drive 45, which may be of a writeable type. The computer system may also be coupled to a network server 47, and form a client node of a local or wide area network. In many typical embodiments, the computer system comprises a laptop or other form of personal computer.

The processor 36 interfaces with a host bus 44 which also interfaces with a bridge circuit 46. The bridge circuit 46 routes data from the host bus 44 to a PCI bus 48. The PCI bus 48 provides a data source to a logic circuit 50 which is provided in the data path between the PCI bus 48 and an IDE bus 52 and floppy drive control bus 54 which interface directly with the respective data storage devices 38, 40, 42, 44, and 46. The PCI bus 48 may also receive data from I/O devices 56 via a PCI to ISA bridge circuit 58.

The logic circuit 50 advantageously includes an encryption engine 60 which operates to encrypt data routed to one or more of the data storage devices 38, 40, 42, 46, or the network server 47 and to decrypt data routed from one or more of these sources when required. The logic circuit 50 will also generally include input and output bridge circuitry 51 to buffer data and convert the data transfer protocol from the PCI format bus 48 to the busses 52, 54, 55 which interface directly with the data storage devices 38, 40, 42, 46 and network server 47.

The encryption engine operates under the control of control logic 62. The control logic, in turn, receives information for controlling the encryption engine from three sources. The first is a memory location which stores a hardware identifier 64. As described above, this hardware identifier 64 may be substantially uniquely associated with the computer hardware. The memory may comprise a non-volatile writeable or read only memory to help ensure essentially permanent storage of the hardware identifier 64. As is also described above, the hardware identifier 64 stored in the memory may be used by the control logic 62 (or alternatively the processor 36) to at least in part derive a key for encryption and decryption of data to and from the data storage devices 38, 40, 42, 46. The control logic may also accept user input as described above to be used as additional information for key derivation.

This generated key may be stored in a key register 66 which also is coupled to the control logic 62. Prior to data being stored or retrieved from the data storage devices 38, 40, 42, 46, the key may be retrieved from the key register 66 for use by the encryption engine 60 during the encryption and decryption processes.

A configuration register 70 may also be coupled to the control logic 62. The content of the configuration register 70

may advantageously be user defined, and may include bits that determine which of the data storage devices **38**, **40**, **42**, **46** have data encrypted before storage to the media, and which have data decrypted when data is retrieved from the media. This feature provides significant flexibility to the user. A user may, for example, want to encrypt some, but not all, data stored onto a floppy disk with the floppy drive **42**. It may also be advantageous to have at least one hard drive **38** or **40**, which contains DOS, Windows™, Unix™, or other operating system software, to remain unencrypted.

The configuration register may also contain bits which determine whether or not user input should be incorporated into the key being used to perform the encryption and decryption. In some embodiments, a different key may be stored for different drives. In this case, some of the keys may be generated with user input, and some without.

One advantageous aspect of the encryption system described herein is that it may be created with relatively minor modifications to currently existing integrated circuits. PCI to ISA and PCI to IDE bridges are well known and understood, and are commercially available from, for example, Intel Corporation. In one embodiment, therefore, an encryption engine, control logic, a key register, and a configuration register may be incorporated into an existing bridge integrated circuit design to produce a portion of the logic circuit **50**. Furthermore, individual EPROM, EEPROM, and ROM memories which include pre-programmed identification codes are available commercially from Dallas Semiconductor of Dallas Tex. as part numbers DS2401 and DS2430 for example. These devices include a unique 48 bit serial number in a ROM storage location which may be utilized as the memory location which stores the hardware identifier **64**. These memory chips are available with a serial I/O interface for reading the identification code and any other stored data. In this embodiment, therefore, a bridge integrated circuit which includes the encryption logic may interface over a serial bus to a separate memory integrated circuit which stores the hardware identifier.

FIG. 4 illustrates a method of key generation and verification which may be implemented with the system illustrated in FIG. 3. In the method of FIG. 4, the control logic **62** (FIG. 3) may be utilized to perform key generation and verification without intervention by the processor **36** (FIG. 3). The method begins at a start state **76**. Following this start block **76**, the system retrieves the hardware identifier **64** (FIG. 3) from the non-volatile memory location where it is stored. This retrieval process may involve the sequential retrieval of a set of data words from the memory as illustrated by the loop defined by blocks **78**, **80**, and **82**. Thus, at block **78**, the control logic **62** may output an initial address to the non-volatile memory to retrieve a first data word comprising a portion of the hardware identifier code **64**. The address may then be incremented at block **80**. If, at decision block **82**, it is determined that the entire code has not yet been retrieved, the system loops back to block **78** and outputs the incremented address to the non-volatile memory to retrieve another segment of the code.

Once the entire code has been retrieved, at block **84** the control logic **62** may then generate and verify the key. As mentioned above, the process of key generation may involve merely storing a concatenation of the data words retrieved at steps **78-82** in the key register **66**. This could occur during the retrieval process, or afterwards. Alternatively, mathematical or logical manipulations may be performed on the retrieved data words prior to their storage into the key register. Key verification may also be performed in a number of ways known to those of skill in the art. For example, a checksum or

CRC field may be provided in the configuration register **70** or control logic **62**. If no user input is utilized in key generation, this field may be generated during an initialization sequence performed during the manufacture of either the logic circuit **50** or a computer system that the logic circuit **50** is incorporated into. If user input is utilized in key generation, this CRC or checksum field may be generated during a password initialization routine when the password to be utilized in key generation is initially entered by the user.

Following key generation and verification, the system moves to a decision state **86**, where the result of the key verification of block **84** is checked. If the key is verified as good, the system moves to block **88**, and the key is used to encrypt and decrypt data during data storage and retrieval operations. There are several reasons why key verification might fail. An error in reading the hardware identifier may cause faulty key generation. Tampering with the logic circuit **50** may also result in incorrect key generation. Additionally, key verification may fail because required operator input to be used in key generation has not yet been entered by a user. Thus, a failure of key verification may force user input. This is illustrated in FIG. 4 by the fact that if, at decision state **86**, the key has not been verified as good, the system moves to another decision state **90**. At decision state **90**, the system determines whether or not user input should be accepted and used in the key generation process. If the system determines that operator input should be accepted, the system moves to block **92**, where the input is read. The system then loops back to block **84**, where the key is generated using both the operator input and the retrieved identification code, and is again verified against the stored CRC or checksum field. If the operator input was the correct password, the key will be verified as good at the next iteration of decision block **86**, and at block **88**, the key will be used to encrypt and decrypt data as described above.

If, however, the operator input was incorrect, the key verification process will fail, and the system will again move to decision state **90**, where the system again determines whether or not user input should be accepted. It will be appreciated that the user may be given two or more attempts to successfully input the proper password. Thus, the system may loop back to blocks **92** and **84** a plurality of times, any one of which may result in correct password entry and normal data encryption and decryption at block **88**.

After a selected number of iterations of incorrect password entry, the system may decide at state **90** to refuse to accept further operator input for key generation. In this event, the system moves to block **94** where the key error is flagged by the system. System response to the error flag may vary widely. The system may indicate to the user that the password entries are incorrect. The system may even be programmed to destroy the content of encrypted drives in the event the key verification process fails, or fails for a selected number of consecutive verification attempts.

The encryption system described thus provides data security to personal and laptop computer users in a transparent manner without requiring time consuming and expensive system administration or complex and expensive hardware. The system is especially adapted to individual users, and the high volume production of computers for these users. In addition, the system can be advantageously utilized to form an easily administrated secure computer networking system.

In the network environment, files which are stored to network drives associated with a network server (FIG. 3) may be encrypted by the local system prior to file transfer in a manner analogous to that set forth above when storing data files to local data storage devices. In this way, a given user's personal

or confidential data may be protected when resident on a network accessible storage resource. In the network embodiment, public key cryptography is advantageously used because public encryption keys can be made available to the network servers and/or clients such that appropriate encryption processes can be performed transparently and without user intervention by different elements of the network.

One example of a method of file transfer in a network embodiment of the invention is illustrated by the flow chart of FIG. 5. It can be appreciated that in a network environment, files may be stored at various dispersed locations. If the transparent encryption during save operations is employed as described above, different files on the same storage device may be encrypted with different keys depending on which client system performed the save operation. In addition, network accessible drives may include unencrypted files as well. Of course, any of these files may be retrieved by a client and stored on their own local drive.

Referring now to FIG. 5, in one embodiment of the invention, at block 100 a request for a file is forward from a client to a network server. At block 102, the network server checks the status of an encryption attribute associated with the file. This attribute is set or cleared depending on whether or not the file is already encrypted on the network server or is unencrypted. If the file was previously stored by the requesting client, the file may already be encrypted with the client's public key. In this case, the attribute would indicate that the file is encrypted, and may in some embodiments additionally indicate the owner of the public key that it was encrypted with. If at decision state 104 it is determined that the attribute indicates the file is already encrypted, then the server sends the file to the client at block 106. Once there, the file is decrypted using the private key stored by the requestor, and is then viewed and/or stored locally.

It is possible that the requested file has been stored on the network server encrypted with a different user's public key. If this information is provided by the file attribute, the system may forward the requesting client a message indicating this fact. If the file is still sent to the requestor, it will of course be unreadable by them because they will not have access to the private key of the user that originally encrypted and stored the file.

If alternatively it is determined at decision state 104 that the file is not encrypted, at block 108 the server retrieves the public key of the requestor. This may be done directly by retrieving the key from the memory location 66 (FIG. 3) where the public and private keys are stored on the requestor's system. It is also possible that the server could have a public key table stored locally from which the appropriate public key is available. Once the requestor's public key is retrieved by the server, at block 110 it uses the key to encrypt the file, and then sends the file to the requesting client where as described above it is decrypted for viewing and/or local storage. Preferably, all of the attribute checking and key retrieval is performed transparently without any user intervention.

The invention thus has advantageous applicability to both stand alone computers and network systems. Files are stored either focally or on a network securely without effort on the part of the computer user. In addition, in the network embodiment, management of the cryptographic system and circuitry in each client computer can be controlled by a central administrator. In this embodiment, the configuration information stored in the memory 70 (FIG. 3) of each client may be accessible and alterable by a network administrator. Which files are encrypted and when could be centrally controlled however the administrator desired. If desired, key generation and distribution could also be controlled by the administrator.

The foregoing description details certain embodiments of the invention. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the invention can be practiced in many ways. As is also stated above, it should be noted that the use of particular terminology when describing certain features or aspects of the invention should not be taken to imply that the terminology is being re-defined herein to be restricted to including any specific characteristics of the features or aspects of the invention with which that terminology is associated. The scope of the invention should therefore be construed in accordance with the appended claims and any equivalents thereof.

What is claimed is:

1. Apparatus configured to store data, the apparatus comprising:

a first apparatus configured to receive an encryption key generated by a first computer, the encryption key uniquely associated at least in part with a user of the first computer;

a second apparatus configured to obtain encrypted data via the first computer, the encrypted data having been generated using the encryption key;

a third apparatus configured to receive a file attribute to be stored, the file attribute in association with the encrypted data denoting the data as encrypted, and further indicating a source of the encryption key;

a fourth apparatus configured to cause an indication of a source of the encrypted data to be stored; and

logic configured to cause the apparatus to:

when a request is received from a requestor for the encrypted data, and the requestor is the source of the encrypted data, forward the encrypted data to the requestor; and

when the request is received from the requestor for non-encrypted data, encrypt the non-encrypted data with the encryption key associated with the requestor and forward the encrypted data to the requestor.

2. The apparatus of claim 1, wherein the logic is further configured to cause the apparatus to, when the requestor is not the source of the encrypted data, send the requestor a message indicating that the encrypted data is not associated with the requestor.

3. The apparatus of claim 1, further comprising a fifth apparatus configured to automatically obtain the encryption key from the first computer to encrypt the non-encrypted data.

4. The apparatus of claim 1, further comprising a sixth apparatus configured to process the request to retrieve the data, wherein the processing comprises a check of the file attribute prior to provision of the data back to the first computer.

5. The apparatus of claim 1, further comprising a seventh apparatus configured to check the file attribute to determine whether the request for data is in unencrypted form prior to encryption thereof.

6. The apparatus of claim 1, wherein the encryption key comprises at least one of a private encryption key and a public encryption key.

7. The apparatus of claim 6, wherein the public encryption key is obtained by the first apparatus from the first computer.

8. The apparatus of claim 6, wherein the first apparatus is configured to store the public encryption key and the encrypted data.

9. A computerized storage system, comprising:

a storage device;

a processor in data communication with the storage device, the processor configured to execute at least one com-

11

puter program comprising a plurality of instructions configured to, when executed by the processor:
 receive a user-specific encryption key;
 receive user-specific information enabling an authorized entity to access first data based at least in part on an association of the user-specific information and the first data;
 encrypt the first data upon a determination that the first data has not been previously encrypted as a first encrypted data, using at least the user-specific encryption key so as to produce the first encrypted data;
 store the first encrypted data and the user-specific information on the storage device;
 receive a request for access to the first encrypted data;
 determine, based at least in part on the stored user-specific information, whether the request is received from the authorized entity; and
 when it is determined that the request is received from the authorized entity, provide the requested first encrypted data thereto.

10. The computer storage system of claim **9**, wherein the plurality of instructions are further configured to, when executed:
 determine that a requesting entity is not the authorized entity of the encrypted data; and
 cause transmission of a message that indicates that the encrypted data is not associated with the requesting entity.

11. The computer storage system of claim **9**, wherein the computerized storage system is configured to obtain the user-specific encryption key from the authorized entity to enable said encryption of the non-encrypted data.

12. The computer storage system of claim **9**, wherein the computerized storage system is configured to check the association of the user-specific information and the first data to at least determine that the first data is in unencrypted form prior to encrypting.

12

13. The computer storage system of claim **9**, wherein the authorized entity comprises a specific user.

14. A method of storing data in a computerized storage system, comprising:
 generating an encryption key using a first computer, the encryption key being uniquely associated at least in part with a user;
 encrypting data using the encryption key and a first computer to generate first encrypted data;
 causing the first encrypted data to be stored on a computerized storage device, the computerized storage device connected via a network to the first computer; and
 providing an attribute to be stored on the computerized storage device, the attribute in association with the first encrypted data (i) designating the first encrypted data as encrypted, and (ii) indicating an association between the user and the encryption key;
 wherein the attribute is configured to cause requested data that has not been previously encrypted to be encrypted using the encryption key to generate second encrypted data, the second encrypted data to be provided to a source of a request for the requested data.

15. The method of claim **14**, further comprising decrypting the first encrypted data by the first computer using at least the encryption key.

16. The method of claim **14**, further comprising decrypting at least a portion of the second encrypted data by the first computer using at least the encryption key.

17. The method of claim **14**, wherein the encryption key associated with the user comprises at least one of a private encryption key and a public encryption key.

18. The method of claim **14**, wherein the act of generating the encryption key is based at least in part on receiving a unique identifier from a storage location within the first computer.

* * * * *